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Discussion Draft for Distribution and Interconnection R&D Strategic Roadmap Meeting January 21-23, 2003

Prepared by
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Acknowledgments

This Strategic Roadmap Discussion Draft has been developed as an outcome of market and technology research, stakeholder interviews and the series of meetings and workshops on this topic conducted over the last two years. Prepared in advance of the Strategic Roadmap meeting scheduled for January 21 – 23, 2003, this document is intended to spur discussion, invite stakeholder critique and hone in on a common vision of the future based on a reinvention of our electric power distribution system. This draft is only a starting point. Through the January meeting interaction and follow-up meetings and discussions, this Strategic Roadmap will be completed, at least on an initial basis. Further steps will be outlined as implementation progress is made and this Strategic Roadmap is accordingly reviewed and updated.

Through a collaboration of industry partners and the national laboratories, the U.S. Department of Energy's *Distribution and Integration R&D* activity is focusing on the efficient and safe integration of distributed energy resources with the electric power distribution system. This draft strategic roadmap discussion document was developed with the input and support of our many industry partners--equipment manufacturers, regulators, customers and other stakeholders who contributed their insight and perspective, both directly and through a series of meetings and workshops conducted over the last two years. The participation of a wide range of supporters has helped clarify the key issues impacting the interconnection market and the challenges we face in modernizing our electric power distribution system to better accommodate distributed energy resources.

January 2003

Executive Summary

As stated in the President's National Energy Policy, the national challenge is to increase the nation's energy production to better match consumption, using technological know-how and environmentally sound, 21st Century technologies. To meet this challenge, the Office of Energy Efficiency and Renewable Energy (EERE) has a mission to strengthen America's energy security, environmental quality and economic vitality, accomplished through public/private partnerships to: enhance energy efficiency and productivity; bring clean, reliable and affordable energy production and delivery technologies to the marketplace; and make a difference in enhancing energy choice and quality of life.

Distribution and Interconnection R&D (formerly the Distributed Power Program) directly supports this mission by conducting research and development to advance efficient, reliable, and secure electric power distribution systems of the future, and to integrate distributed energy resources (DER) into these existing and future systems.

DER are grid-connected systems that can be integrated into residential, commercial, or institutional buildings and/or industrial facilities. These distributed energy systems can include renewable energy, advanced technologies such as fuel cells, hybrid generation and energy storage. DER also include efficiency and demand-side energy management tools, such as combined heat and power (CHP) and demand response.

Characteristics of advanced distribution systems include:

- Adaptable and re-configurable to meet contingencies (such as local disruptions in service or changing load demands),
- Support competitive markets,
- Incorporate distributive architectures for control and generation resources, and
- Fully integrated to accept distributed generation from a range of resources.

To achieve the modernized systems of the future, critical R&D is essential. Work in *Distribution and Interconnection R&D* focuses on the electric distribution system, from the substation through the interconnection system of the distributed energy resource. To progress toward these goals DOE has developed the concept of SMARTConnect™. SMARTConnect™ consists of a set of technology platforms that support the development of a modernized, reliable, highly automated and more efficient electric power distribution system with fully-integrated distributed energy resources. SMARTConnect™ activities encompass technology R&D developments in the following areas:

1) DER technology communications and controls.
2) Interconnection system technologies.
3) Electrical distribution system technologies.

Interconnection is key to the efficient and safe integration of DER into today's electric power systems, and a critical component of the electricity infrastructure of the future. Interconnection devices today perform the functions necessary to maintain the safety, power quality, and reliability of the electric power system when DER are connected to it. These devices should regulate, for example, the harmonics, voltage variations, and DC current injected into the grid; prevent inadvertent action of system protection devices due to DER; and prevent unintentional islanding.

DER offer unique benefits to power companies and customers that are not available from the traditional centralized electricity generation approach. Moving energy to the point of end-use from such technologies as microturbines, reciprocating engines, small gas turbines, and energy storage promises important economic, environmental, and reliability advantages. The direct benefits of DER include efficient and cost-effective power resources, power in locations where there are no utility services, increased potential for use of otherwise wasted energy, and interconnection with the grid for the sale of surplus power to meet electricity demand or provide peaking power. In addition, DER offer end-users increased choice through diversified fuel supply for security and reliability, and are a critical component when it is necessary to improved power reliability and quality, greater efficiency, or lower emissions than available from traditional central station based supply.

Decentralized energy resources offer significant advantages over conventional grid electricity. Compared to conventional energy technologies, distributed energy resources:

- **Offer more choice in fuel supply options**
- **Reduce siting and permitting costs and delays**
- **Can achieve higher energy conversion efficiencies than central station generation**
- **Can deliver greater power quality and reliability**
- **Can be quieter and less polluting**
- **Allow for greater local control of electricity delivery and consumption**
- **Recover and re-use waste heat in combined heat and power applications**
- **Can meet baseload/peak-shaving/backup/remote/grid support power needs**
- **Significantly reduce line losses**
- **Decentralize and strengthen the conventional power paradigm**
- **Create greater flexibility to respond to changing energy needs**
- **Reduce or defer line and substation upgrades**

DER also allows for greater flexibility to respond to changing energy needs, as several distributed power technologies are inherently modular, thereby enabling capacity changes in small increments that can closely match demand. Distributed energy resources also typically reduce the load at the distribution level of the transmission and distribution grid, thus helping increase the reliability of the electricity system.

The many potential benefits of DER make it an important tool for meeting the energy challenge enunciated in the National Energy Policy and the EERE vision and goals for the future. However, the technologies and operational concepts to properly integrate DER into today's distribution system must be more fully developed to realize these benefits while improving system reliability and safety. Today's existing power distribution system was not designed to accommodate generation and storage at the distribution level, particularly to supply energy to other distribution customers. For the distribution system of the future, these technical issues need resolution. New interconnection technology and systems integration techniques are needed, along with the hardware and software to implement them.

In preparation for the distribution system of the future, *Distribution and Interconnection R&D* incorporates activities to develop technologies and policies enabling distributed generation, storage and direct load control technologies to be integrated into electric distribution systems. Through collaborative work by the national laboratories and industry partners, *Distribution and Interconnection R&D* is conducting focused work in the following five areas:

1. Technical standards for interconnection,
2. Interconnection technologies to facilitate the grid of the future,
3. Electrical distribution systems research, development and deployment,
4. Mitigation of regulatory and institutional barriers, and
5. Testing and certification of equipment for DER distribution and interconnection systems.

Through this work *Distribution and Interconnection R&D* will develop concepts, technologies, and standards to integrate DER with electric power systems and develop advanced electric distribution systems. In addition, *Distribution and Interconnection R&D* is working to complete national standards for DER interconnection and integration, facilitating and implementing DER field validation, and is supporting R&D of system integration technologies for the interface and control of DER with local energy systems, including specialized applications such as power parks and other microgrids.

During FY 2003, R&D on distribution system architectures, operational concepts and technologies will be initiated. These technologies are key to realizing the full value of DER and for achieving the necessary DER functionality that will ensure effective utilization for reliability support and ancillary grid services.

Goals

Distribution and Interconnection R&D supports developing technologies and activities to enhance electrical distribution systems and enable distributed generation, storage and direct load control technologies to be integrated into the distribution system of the future. Specific goals include:

1. By 2010, develop and publish a body of technical standards facilitating the commercialization of mass-produced, certified interconnection equipment – simplifying the interconnection process.
2. By 2010, develop a modular interconnection device that allows plug-and-play interconnection of DER equipment.
3. By 2010, identify and remove regulatory and institutional barriers to DER.
4. By 2015, develop next generation distribution technologies that make distribution systems more efficient, adaptable, reliable, secure, and fully integrate DER.

Metrics and Performance Targets

Specific metrics and performance targets are summarized in Table ES-1. Related testing and certification activities are noted within the table's four activity areas.

As part of the effort to prepare for the distribution system of the future, overall costs must be reduced. Current interconnection systems can account for one-third to one-half of the installed cost of a DER system and have been known to stop installation of some DER. An overall goal of *Distribution and Interconnection R&D* is to substantially reduce these costs, opening the market for DER to more customers. By 2010, program activities target a reduction of 30 percent of the overall cost of interconnection.

With collaboration among the electricity industry, national laboratories and universities, *Distribution and Interconnection R&D* can help create the bridge from today's distribution system to tomorrow's distribution system that unleashes the potential of DER.

Table ES-1. Targets and Timelines for *Distribution and Interconnection R&D*

Performance Target	Year
Technical Standards	
IEEE P1547, DER interconnection standard, approved	2002
IEEE P1547 published	2003
IEEE P1547.1, Testing for DER Interconnection Systems, voting draft	2004
IEEE P1547.2, Application Guide for DER Interconnection, voting draft	2004
IEEE P1547.3, Guide for Monitoring Information Exchange, voting draft	2005
P1547 Revisions approved	2007
Distribution system standards review	2007
Interconnection Systems	
NREL DER system integration test facility operational	2002
Complete preliminary integration test at the Nevada Test Site	2002
Phase I multiple DER interaction field testing	2003
Complete phase II multiple DER interaction field testing	2005
Reduce overall cost of interconnection by 15%	2005
10-year mean time between failures (MTBF) for inverter-based technology	2005
Inverter-based interconnection system across multiple technologies	2006
Fully integrated switchgear system for machines less than 3 MW	2006
Electrical Distribution Systems	
Distribution system technology and needs assessment	2003
Operational and technical concepts for intentional islanding	2004
Interconnection certification process	2004
Advanced protection technology for DER and system reconfiguration	2005
Demonstration of micro grid operation	2005
Sensors and control research and development	2006
Advanced grid control, advanced SCADA, smart substations	2007
Mitigation of Regulatory and Institutional Barriers	
UL/ANSI 1741 standard/certification process to cover interconnection equipment for all DER	2003
Model DER interconnection rule	2003
Model emissions rule for small DER	2003
Method to determine equitable rates for standby charges and backup fees	2004
Innovative tariffs for DER	2005
10 states adopt DER interconnection rule	2005
10 states adopt DER emissions rule	2005

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1 Introduction

This Strategic Roadmap Discussion Draft has been developed as an outcome of market and technology research, stakeholder interviews and a series of meetings and workshops on this topic conducted over the last two years. Prepared in advance of the Strategic Roadmap meeting scheduled for late January 2003, this document is intended to spur discussion, invite stakeholder critique and hone in on a common vision of the future based on a reinvention of our electric power distribution system. It is through this process and through the application of the SMARTConnect™ concept outlined in this document that the full benefits of DER integration can be realized.

This draft is only a starting point. Through the January meeting interaction and follow-up meetings and discussions, this Strategic Roadmap will be completed, at least on an initial basis. While the ensuing Roadmap will depict the detailed activities and challenges of the *Distribution and Integration R&D* activity, its development will not stop there. The Roadmap is expected to evolve as the R&D activities progress and begin to show results. This draft depicts details for the next 5 years, but ongoing efforts are expected for the next couple of decades as the electric distribution system evolves into a smart, reliable and highly automated system with full DER integration. Further steps will be outlined as implementation progress is made and this Strategic Roadmap is accordingly reviewed and updated.

2 Strategic Goals

2.1 A Foundation for Reinventing the Electric Power Distribution System

DOE has been leading an effort to conduct RD&D on interconnection and distribution system integration technologies and on regulatory activities to remove technical, institutional and regulatory barriers that are impeding realization of the full potential of distributed energy resources (DER). In doing so, DOE is helping create a foundation that will reinvent the electric power distribution system.

The Federal government has an interest in the systems aspects of distributed power because of its impact on competition in the electric industry, the reliability and security of electric power supply, and the environment; and because barriers remain that limit use of distributed generation and storage devices improved by Federal investments.

It has been suggested that true retail competition in the electric industry will only occur with significant penetration of distributed power technologies. A robust market for distributed generation is a giant step forward in ensuring that market power for electric supply will not be concentrated in the hands of a few. Even if the wholesale electricity market is dominated by a few generating companies, the cost of self-generation can set the upper limit for the price consumers need to pay for electricity, only if that is a viable option for most consumers.

The Federal government has spent and will spend billions of dollars on DER R&D. Systems issues that are fundamental to employing these technologies in the real world must also be addressed if DER use is to grow quickly. The systems issues related to distributed power are national issues and impact a number of industries. There is a Federal leadership role in bringing together these various parties – hardware manufacturers (of photovoltaic, wind, fuel cell, gas turbine, batteries, etc.), utilities, energy service companies, codes and standards organizations, state regulators and legislators, and others, to address the technical, institutional and regulatory barriers to distributed power. In fact, these very groups have asked the Federal government to help facilitate these efforts. States have begun a piecemeal approach to addressing these issues, but neither the states nor industry see this as satisfactory. They feel a national approach is essential to creating a viable market for distributed power.

2.2 Improved Interconnection and Distribution Systems Offer a Wide Range of Benefits

The United States has about 67,000 MW of isolated standby generation at least 10 kW in size, representing about 10% of system peak load[1]. If interconnected, these standby generators could provide power during energy shortages. Interconnection would allow utilities to turn backup generators into peak-shavers and grid-supporting units providing benefits to both the end-user and the utility while making the grid more secure.

Depending upon a user's requirements, distributed energy resources can offer significant advantages and supplement conventional grid electricity. However, the technologies and operational concepts to properly integrate DER into the power system must be developed to realize these benefits and avoid negative impacts on system reliability and safety. The national power distribution system was not designed to accommodate active generation and storage at the distribution level, particularly to supply energy to other distribution customers. The technical issues to allow this type of operation are significant. New interconnection technology and distribution systems integration techniques will need to be developed along with hardware and software that enable these to be implemented.

2.3 Bridge to the Future

Distribution and Interconnection R&D's efforts help create a "bridge to the future" to meet DOE's DER market penetration goal of 20 percent of additional generation capacity by 2020. It does so by reducing the cost of DER systems integration and interconnection with the grid, by enabling DER to participate in markets for grid support and ancillary services, and by removing regulatory and institutional barriers. The *Distribution and Interconnection R&D* vision by 2020 is to:

- Achieve a modernized electric distribution system,
- Standardize interconnection requirements,
- Deploy affordable reliable modular interfaces and intelligent adaptive control technology, and
- Develop a regulatory and institutional environment that recognizes the benefits of DER and supports its use.

Together, these will enable DER to become a significant contributor to a reliable and secure electric supply, a clean environment and a highly productive economy.

2.3.1 Supports National Energy Policy Goals

Distribution and Interconnection R&D activities support Chapter 7 of the National Energy Policy (NEP) recommendations to develop a comprehensive energy delivery system[2]. *Distribution and Interconnection R&D* supports the NEP goals of modernizing conservation, modernizing the energy infrastructure, increasing energy supplies, accelerating protection and improvement of the environment, and increasing energy security. The Policy's 105 recommendations include several that reference DER, and recommend an expansion of research in the area of transmission reliability. *Distribution and Interconnection R&D* supports these goals through a variety of activities, as outlined in Table 1.

Untapped opportunities for reducing energy demand loads could be realized by better integrating electricity supply systems and customers. Improved integration can produce a variety of benefits for tight energy markets, including reducing peak demand loads, bypassing congested areas of transmission by placing new generating capacity closer to the consumer, and thus achieving greater overall system efficiencies.

National Energy Policy, May 2001

[1] *The Installed Base of U.S. Distributed Generation*, Table 6, Resource Dynamics Corporation, December 2002.
[2] *National Energy Policy*, http://www.whitehouse.gov/energy, May 2001.

Table 1. Support of National Energy Policy Goals

NEP Goal	How Distribution and Interconnection R&D Activities Support NEP Goals
Modernize our energy infrastructure	Reliable delivery of energy, including electricity, increasingly depends upon a complete infrastructure that integrates power generation and demand response into an efficient and reliable delivery network. DER technologies and their integration into end-use customer facilities often pose technological and regulatory challenges. They need standardized interconnection protocols and the removal of regulatory and institutional barriers. The DER Distribution and Interconnection R&D is focusing on interconnection protocol development and barrier mitigation.
Modernize conservation	The President's NEP goal of modernizing energy conservation recognizes that using advanced technologies can improve energy efficiency. The DER Distribution and Interconnection R&D seeks to create a "DER-friendly" national electric grid that will support the efficient use of electricity generated at the end-use location.
Increase energy supplies	Distribution and Interconnection R&D is directly addressing impediments to the increased use of distributed power generating technologies. Additionally, some combined heat and power DER technologies use waste gas that was previously being flared off.
Increase energy security	Distribution and Interconnection R&D is developing interconnection and control technologies and protocols that will enable DER to operate as an island, effectively making our domestic electricity infrastructure less vulnerable to disruptions from either natural or manmade events.
Accelerate protection and improvement of the environment	The NEP emphasizes the need to accelerate the protection and improvement of the environment while, at the same time, ensuring an adequate energy supply. Distribution and Interconnection R&D is sponsoring development of a model emissions rule that will clarify the impact of DER on the environment.

With the fulfillment of this vision and mission over the next two decades, industrial, commercial, institutional, and residential customers will be able to choose from a diverse array of ultra-high efficiency, ultra-low emission, fuel-flexible, and cost-competitive DER products and services. These will be easily interconnected into the nation's infrastructure for electricity, natural gas, and renewable energy resources.

2.3.2 Supports Energy Efficiency and Renewable Energy Strategic Plan

Table 2 demonstrates how *Distribution and Interconnection R&D* activities also support 4 goals stated in the Energy Efficiency and Renewable Energy (EERE) strategic plan[3]:

- Reduce dependence on foreign oil.
- Reduce the burden of energy prices on the disadvantaged.
- Increase the viability and deployment of renewable energy.
- Increase reliability and efficiency of electric generation, delivery and use.

> **The importance of reliable and secure electricity is growing in our increasingly information-based economy. New technologies and system designs will be needed to modernize our electricity infrastructure and to provide reliable power, especially during periods of peak demand**.
>
> *EERE Strategic Plan, October 2002*

[3] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy *Strategic Plan*, www.eren.doe.gov, October 2002.

Table 2. Support of Energy Efficiency and Renewable Energy Goals

EERE Goal	How Distribution and Interconnection R&D Activities Support EERE Strategic Plan Goals
Reduce dependence on foreign oil	By significantly reducing the installed costs for small distributed fuel cell, wind and photovoltaic systems; and by facilitating the employment of DER for electric transportation systems, such as light rail.
Reduce the burden of energy prices on the disadvantaged	By increasing the effective utilization of the existing distribution system infrastructure, and reducing the cost of distribution system maintenance and operation which accounts for half of the retail price of electric service.
Increase the viability and deployment of renewable energy	By reducing the cost of interconnection which can account for 1/3 or more of the installed costs of DER systems 100 kW or less in size; and removing regulatory and institutional barriers.
Increase reliability and efficiency of electric generation, delivery and use	By modernizing the electric distribution system; and developing intelligent energy management technology to optimize the application of DER for peak load management, reliability and power quality, grid support, and ancillary services to the grid.

Distribution and Interconnection R&D activities also support many of the "visions" listed in the EERE strategic plan, including:

- Our homes, businesses, and communities will generate much of their power from renewable resources and sell excess energy back to local generators,
- Our factories will become energy parks that both use and make energy, and
- Our electricity infrastructure will be revitalized, more robust, and more reliable.

In brief, the activities outlined in this Strategic Roadmap are fundamental to implementing the EERE strategic plan.

2.3.3 Supports National Transmission Grid Study Recommendations

Electricity is a cornerstone on which the economy and the daily lives of our nation's citizens depend. This essential commodity has no substitute. Unlike most commodities, electricity cannot easily be stored, so it must be produced at the same instant it is consumed. The electricity delivery system must be flexible enough, every second of the day and every day of the year, to accommodate the nation's ever changing demand for electricity. There is growing evidence that both private and public action are urgently needed to ensure our transmission system will continue to meet the nation's needs for reliable and affordable electricity in the 21st century.

National Transmission Grid Study, May 2002

To meet forecasted growth in demand for electricity, substantial additions are needed to develop the transmission and distribution (T&D) system. The National Transmission Grid Study[4] projects that $450 billion will be spent in T&D upgrades in the U.S. during the next 20 years. DER can, at least in part, be an alternative to this T&D build out. Two of the study's specific recommendations were 1) "DOE will continue to work with the National Governors Association, regional governors' associations, and the National Association of Regulatory Utility Commissioners to remove regulatory barriers to voluntary customer load-reduction programs, and targeted energy-efficiency and distributed-generation programs that address transmission bottlenecks and lower costs to consumers." and 2) "DOE and the national laboratories will continue to develop cost-effective technologies that improve the security of, protect against, mitigate the impacts of, and improve

[4] U.S. Department of Energy, *National Transmission Grid Study*, http://tis.eh.doe.gov/ntgs/reports.html, May 2002.

the ability to recover from disruptive incidents within the energy infrastructure." In these and related ways, *Distribution and Interconnection R&D* activities also support implementation of this study's recommendations.

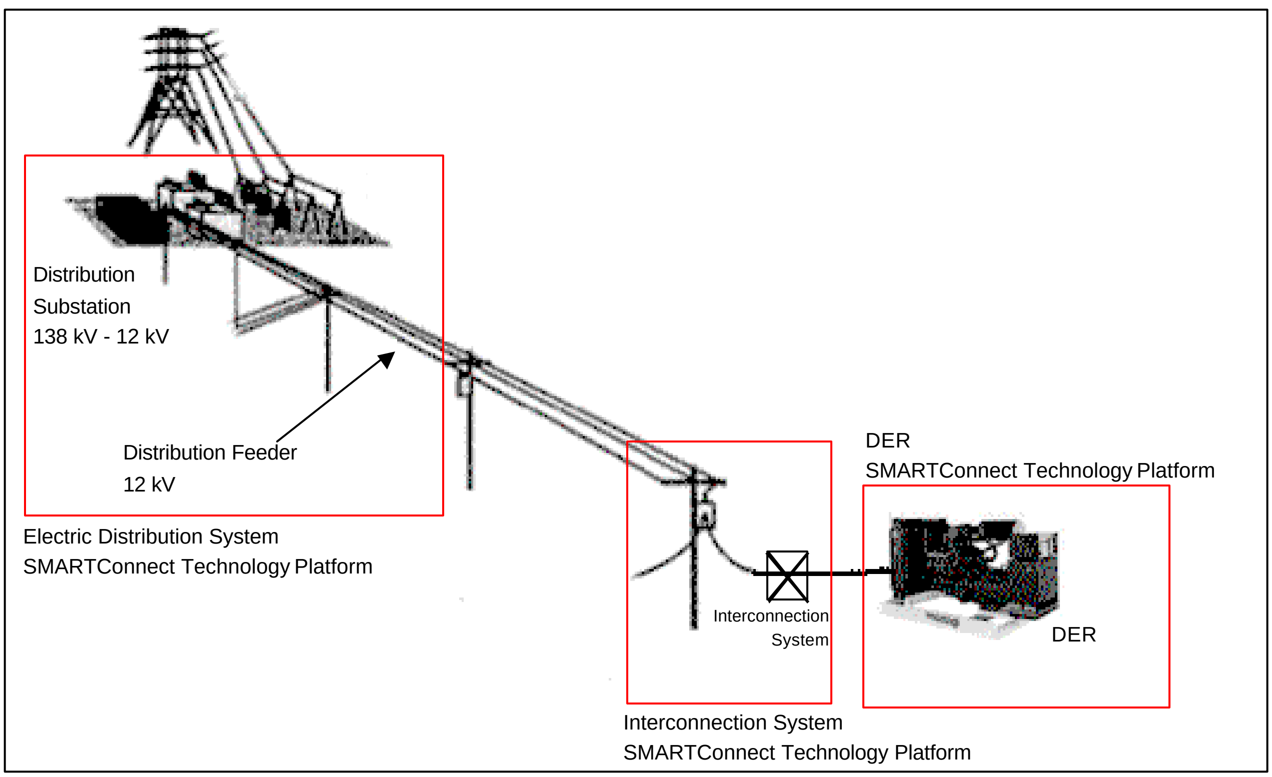
2.4 SMARTConnect™ and DER Integration

To progress toward these goals and meet these recommendations, DOE has developed the concept of SMARTConnect™. SMARTConnect™ consists of a set of technology platforms that support the development of a modernized, reliable, highly automated and more efficient electric power distribution system with fully-integrated distributed energy resources. These technology platforms are shown in Figure 1 and encompass technology R&D developments in the following areas:

1) DER technology communications and controls.
2) Interconnection system technologies.
3) Electrical distribution system technologies.

DER SMARTConnect™ technologies include a wide range of relays, other controls and devices that will allow DER units of all technologies and sizes to be plug-and-play with the electrical distribution system. Interconnection system SMARTConnect™ technologies include many of the same relays and controls sometimes found within the DER package, as well as a host of other technologies including 2-way communication capability. Electrical distribution system SMARTConnect™ technologies will handle 2-way electrical flows as well as communications that permit all interconnected DER to be dispatched, monitored, and controlled from a central source, and rely on upgraded smart substations that incorporate remote terminal units (RTUs) with improved capabilities for monitoring and reporting, GPS, electric equipment diagnosis, real-time video capturing and transmission, audio signature analysis and substation security supervision.

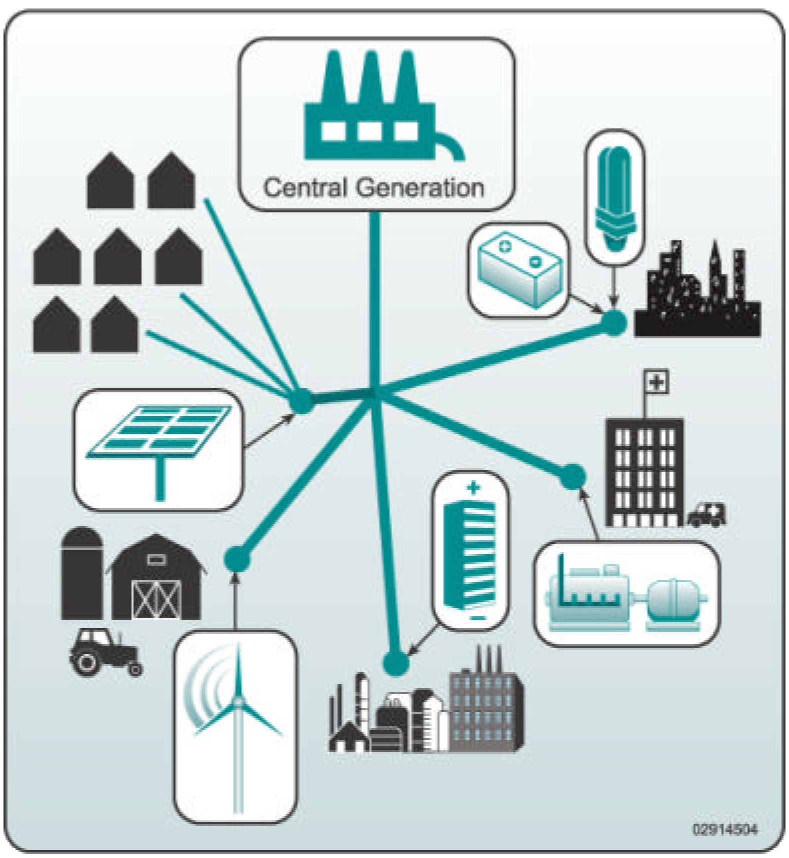
Figure 1. SMARTConnect™ Technology Platforms



To better understand the SMARTConnect™ concept, it is helpful to understand why DER are different than traditional generation. DER can be distinguished from centralized energy resources in several respects. DER are small, modular, and come in sizes that range in capacity from kilowatts to megawatts. They comprise a portfolio of technologies, both supply- and demand-side, that can be located on-site or nearby the location where the energy is used. This provides the opportunity for greater local control and more efficient waste heat utilization to boost efficiency and lower emissions. DER systems range in size and capacity from a few kilowatts up to 50 MW. The portfolio of DER technologies includes photovoltaic systems, fuel cells, natural gas engines, advanced turbines and microturbines, energy storage devices, thermally activated cooling systems, humidity control equipment, wind turbines, demand management devices, concentrating solar power collectors, and geothermal energy systems. The SMARTConnect™ DER technology platform allows seamless integration with the electrical distribution system, at the same time supporting customer energy needs such as continuous power, backup power, remote power, combined heat and power (CHP), and peak shaving. An important point to note is that the specific SMARTConnect™ technologies may be located within the DER system package, or in some cases will be within the interconnection system itself.

When properly integrated through the application of SMARTConnect™ technologies, DER supports and strengthens the central-station model of electricity generation, transmission, and distribution. Figure 2 shows how the grid looks after the addition of DER to the power grid. While the central generating plant continues to provide most of the power to the grid, the distributed resources meet the peak demands of local distribution feeder lines or major customers. One vision of the future is that all the devices and technologies comprising the different elements of Figure 2 will be certified "SMARTConnect™ compatible".

Figure 2. The Grid with DER



The growing popularity of DER is analogous to the historical evolution of computer systems. Whereas we once relied solely on mainframe computers with outlying workstations that had no processing power of their own, we now rely primarily on a small number of powerful servers networked with a larger number of desktop personal computers, all of which help to meet the information processing demands of end-users.

And just as the smaller size and lower cost of computers has enabled individuals to buy and run their own computing power, so the same trend in generating technologies is enabling individual business and residential consumers to purchase and run their own electrical power systems.

However, there are barriers that impede easy integration of DER with the grid today. The SMARTConnect™ technology platforms are expected to be major contributors in lowering these barriers.

3 Key Barriers

Barriers to the quick and easy adoption and integration of DER with the grid today arise because of the historic design of the electrical distribution system, technology constraints, and regulatory constraints. Key challenges are now reviewed that need to be addressed to fully achieve the benefits described in Section 2. At the outset, it is important to recognize that many of the necessary R&D technology activities must and will be conducted by private industry, while at the same time many of the regulatory and institutional change activities are best facilitated by government. Proposed solutions exist that mitigate each barrier, and after being introduced in this Section, they are described more fully in Sections 4 and 5.

3.1 Forty to Sixty-Year Old Grid Design Technology

The traditional model of electric power generation and delivery is based on the construction of large, centrally located power plants and is characterized by a grid design that is forty to sixty years old. "Central" in this case typically means power plants located in a hub surrounded by major electrical load centers. For instance, a power plant may be located close to a city to serve the electrical loads in the city and its suburbs, or a plant may be located in the midpoint of a triangle formed by three cities.

Electric power grids consist of two separate infrastructures: the high-voltage transmission and lower voltage distribution systems. High-voltage transmission systems carry electricity in the range of 138 kV to 765 kV from large power plants and transmit it, if needed, many hundreds of miles away. Examples include high voltage lines transmitting power from hydroelectric plants in the Pacific Northwest to southern California. High-voltage is used for transmission lines and minimizes electrical losses. Lower-voltage distribution systems, which draw electricity from the transmission lines at substations, step the power down to 14 to 35 kVa or less for distribution to individual customers. Transformers located along the distribution lines further step down the voltage to 120 V or 240 V for household use.

Substations contain electrical switchgear and circuit breakers to protect the transformers and the high-voltage transmission system from electrical failures on the distribution lines. Beyond the substation, circuit breakers are located along the distribution lines to locally isolate electrical problems (such as short circuits caused by downed power lines).

A major barrier to DER interconnection is that the electric grid was not designed to accommodate active generation and storage at the distribution level, particularly two-way distribution where a local residence or business, for example, is sending power back into the distribution system when it is producing more power than needed. With a 40 to 60 year old grid designed for one-way power flow, additional steps are required to safely interconnect DER to address system protection, metering, and basic design difficulties.

Existing distribution grids must be evaluated to determine if they can be modified to accommodate interconnected DER. DER can obviate or reduce the need to build both new high voltage transmission as well as the lower-voltage distribution lines. As another plus, overall efficiency improves by limiting or eliminating line losses, the power losses that occur when electricity travels over transmission lines for long distances to the end-user. These benefits are becoming more important with the unbundling of T&D tariffs. Many solutions will likely be specific to utility feeder designs. It is also likely that some solutions will have wide, though not universal, application.

Distribution systems were not designed to accommodate large amounts of DER and potential problems are well documented. DER designs that reduce or eliminate problems with the existing utility distribution system are not well developed. Similarly, additional R&D is needed to minimize the cost of modifying utility distribution system protection systems to accommodate increased amounts of DER. The advanced utility distribution system of the future will be fully capable of extracting the full benefits offered by DER for both the DER owner and for other customers on the distribution system. Once developed, advanced utility distribution systems may not cost any more to design and install than conventional systems.

Distributed energy technologies are clearly capable of supporting electric grid reliability, assuming uninterrupted fuel supply to the generators. The fuel for most new DER projects planned for the next several years will be natural gas. Natural gas also has a distribution system, which, although constructed differently from the electric power T&D grids, is in need of improvements as well. A major issue needing attention is the ability of the natural gas supply system to deliver the gas needed by an increased number of distributed, on-site generators. Integration of gas-fired distributed generation into both the electric and natural gas systems for maximum efficiency, security, and reliability must also be addressed. And finally, since energy security is increasingly important, measures must be evaluated to protect both the electric and gas delivery systems from deliberate attack.

To address all these barriers, the electrical distribution system will need to be modified in several important ways, especially utilizing emerging digital technologies that are more reliable, flexible, and maintainable at lower cost. Such activities are called for in the Strategic Roadmap.

3.2 Limited Distribution System Monitoring and Automation Capability

Distributed energy resources use sensors and control systems for measuring power output, revenue metering, conveying real-time price signals, data acquisition, and communications. Remote dispatch of distributed energy resources can be a cost effective means for aggregating dispersed power supplies, or demand management capabilities, into larger resources to support grid operations. Currently, distributed system monitoring and automation capacity is limited.

To address this challenge, efforts are underway to develop interconnection technologies that provide these capabilities and are cost effective for smaller scale power generation devices. The interconnection system has a preeminent role in providing this monitoring and automation. In preparing for the electric power system of the future, *Distribution and Interconnection R&D* considers ways to improve monitoring and command and control functionality. Another DOE activity, *Communications and Controls*, is focusing on related information technology infrastructure issues.

The Strategic Roadmap suggests that efforts to incorporate advanced sensors and controls within the substation, the electrical distribution system, and the DER interconnection device will mitigate this barrier. These enabling communications and control technologies will optimize the off- and on-grid operations of distributed energy components, subsystems, and systems. Through these enabling communication and control technologies, various DER hardware and software components can be aggregated into an integrated operation with scalability to meet individual user, facility, and utility requirements. Further, such enhanced information flow and system control capabilities allow the practice of demand-side management. When this demand-side management is combined with an increased supply from the aggregated capacities of DER systems, the true values and benefits of DER can be fully realized to meet the nation's power generation, transmission, and distribution challenges.

3.3 Limited Experience with Small Customer Generation

The distribution grid and its associated control system infrastructure have evolved over the years to handle conventional turbine generators. Controls are designed that use large generator characteristics to respond to disturbances. From an electric system perspective, the main disadvantage of DER is that they do not behave like conventional large turbine generators. Many aspects of integrating DER with the grid are still in the process of being understood and standardized. Barriers include incomplete information about how DER interacts with the grid, and the stability and interaction of inverters, synchronous generators and induction generators with various loads and system components.

Specific solutions need to address the interconnection, interface, operation, information sharing, monitoring, and control of DER with electric power systems. R&D involving feasibility and/or engineering studies of fuel-flexible DER systems including alternative fuels, hydrogen systems, or multi-fueled systems may also help mitigate barriers.

The Strategic Roadmap calls for advances in low-cost communications networks, sensors and controls, energy storage, and power electronics that will enable the connection of large numbers of DER to the grid in a fully functional manner and will result in greater reliability, improved efficiency, and improved power quality. Additionally, the Strategic Roadmap outlines standards developments, DER testing and certification efforts that will determine how to best deploy DER as part of the electrical distribution system.

3.4 Regulatory and Institutional Barriers

Achieving the economic and environmental benefits projected for DER also requires removing regulatory barriers to utilizing these resources. There are commercially viable DER systems today that developers have trouble getting installed because of roadblocks in siting, permitting and interconnecting.

Barrier mitigation requires establishing national interconnection standards; reducing the cost and time required for interconnection; developing intelligent interconnection technology; and establishing an improved regulatory and institutional environment. Analyses of existing alternative technical approaches and policy options, such as regional output-based emissions standards, may also help mitigate barriers.

Other priority regulatory and institutional needs include developing streamlined siting and permitting processes for DER installations including pre-certification of small, packaged DER systems; pre-certification guidelines for states; development of permitting guidance and building codes and standards for local zoning, building, fire, and safety code officials; development of "model" codes for policy makers; and the development of tool kits for developers.

The Strategic Roadmap calls for the development and use of nationally adopted interconnection standards, testing procedures, and certification recognition of DER equipment. These efforts will help state and local officials, in energy offices, public utility commissions, air quality offices, building departments, and safety-related agencies make sense of DER and its interconnection requirements. This should in turn allow developers and utilities to more cost-effectively deploy DER.

Overcoming the barriers noted in Section 3 will require R&D and implementation efforts by both industry and government. Current and future R&D efforts are outlined in the next Section.

4 The R&D Foundation and Priority Needs

4.1 Recent R&D Efforts

A number of interconnection and distribution system-related R&D efforts are underway that complement and support proposed *Distribution and Interconnection R&D* efforts. These are important to understand in order to define where and how DOE's efforts can best leverage off of previous and ongoing efforts. Recent activities by manufacturers, trade associations, and the DOE are summarized below to illustrate the nature and extent of current interconnection R&D.

4.1.1 Manufacturers

DER manufacturers, interconnection equipment manufacturers, and distribution system equipment manufacturers have been working to improve their systems and reduce costs. Generally, the industry is moving toward the use of more integrated power electronics technology. There has been considerable work on new inverter-based interconnection technologies as well. One goal is to use this equipment to dynamically improve power quality for a digital economy that demands perfect power.

Trends in manufacturer R&D include:

- A movement toward integrating interconnection equipment with the genset. Some manufacturers have built-in to their gensets fully integrated industrial control systems for all engine, power plant, load balancing, switchgear control, and safety shutdowns. They have eliminated switchgear systems through the application of advanced digital technology, thereby decreasing the DER footprint and reducing cost.
- Use of more reliable, lower cost components. Often this involves digital design and the use of advanced processors. As better electrical components are designed and manufactured, they are being built into interconnection and distribution system components.
- More convergence of hardware and software components in protective relaying and communication devices, creating lower cost, higher reliability, and improved functionality. In turn improved communication and telemetry has led to increased automatic deployment of switchgear, including early efforts at web-based DER dispatch.

Specific recent industry efforts are:

- Improving protective relay performance,
- Producing more accurate and reliable meters,
- Increasing surge withstand immunity,
- Improving communication and control device flexibility so that components may be networked,
- Adapting communications and control systems to handle multiple gensets,
- Increasing the type of information logged by data systems and improving event sequencing analysis,
- Providing better feedback and alarm controls for a larger variety of electronic metrics, and
- Providing controls for real-time operation and monitoring.

4.1.2 Trade Associations

EPRI. The Electric Power Research Institute has studied the interconnection situation over the last few years. EPRI activities in this area include their Distributed Resources program, the Consortium for Electric Infrastructure to Support a Digital Society (CEIDS), and the Distribution Program, a part of the EPRI Power Delivery Reliability Initiative.

Their DER Program seeks to help participants achieve competitive advantage by way of direct application of new DER technology, new business ventures or investments, or through support for customer or third-party DER activities. The major targets of this program include Target 33, Emerging Distributed Resource Technologies, and Target 34, Distributed Resources: Information to Support Business Strategies. EPRI's efforts focus on DER hardware (assessment, validation, demonstration) and also DER business strategies and markets. This includes designing distribution system communication and controls to integrate multiple DER and end-use appliances, extending the functionality of SCADA systems to improve their performance and reliability, and ensuring timely distribution system infrastructure replacement.

Under the CEIDS initiative, EPRI has identified the following three strategic elements that have priority in research and development:

- Self-healing grid,
- DER integration (includes both power systems and consumers), and
- Digital technology solutions including embedded solutions.

The "Distribution Reliability Initiative" is a utility-funded program that provides information and tools to help electric utilities ensure and improve the reliability of their service in the immediate future. It provides a summary report and a living knowledge base of good distribution practices as obtained from 1) audits of representative distribution utilities and 2) self-assessments provided by utilities themselves using a self-guided reliability template tool specially developed for this purpose.

GTI. Since 1999 GTI has worked to develop state-of-the-art switchgear, controls and communication systems through a program they call Integrated Switchgear and Interconnection Systems (ISIS). The goals of the ISIS program are:

- Reduction in interconnection capital costs (25-50%),
- Plug-and-play simplicity (50% reduction in installation time and labor),
- Integration with leading natural gas engine and turbine generator set manufacturers,
- Conformity with basic Area EPS interconnection requirements and use of advanced interconnection/generator set protective functions,
- Compliance with existing or projected industry standards and certifications, and
- Adoption of advanced remote monitoring, communications, and control functions.

These goals are compatible both with what manufacturers are commercializing today and what the government hopes to accomplish in the future through its R&D programs. Finally, recent GTI efforts with Underwriters Laboratories, Inc. have been investigating testing protocols for DER equipment.

4.1.3 DOE

The manufacturer and trade association activities are part of the industry's competitive effort to build less expensive, more reliable, and more flexible components with greater functionality. Over the last few years, the *Distribution and Interconnection R&D* activity has been working with these manufacturers and trade associations to conduct R&D on interconnection and distribution systems and in testing these systems.

Distribution and Interconnection R&D has a number of contracts that contain a broad range of collaborative R&D activities supporting the program's objectives, including:

- **Interconnection and Control Technology.** To effectively integrate distributed resources into an electric power system, interconnection and control technologies are extremely important. The goal here is to develop an advanced modular interconnection technology (one platform of SMARTConnect™ technology) that can provide cross-DER platform capability and increased functionality for load management and grid support. Advanced control and monitoring technologies and operational concepts are also being developed to enhance the integration and aggregation of DER with electric power systems.

- **Interconnection and Distribution System Testing.** DOE conducts tests on distributed power systems at the National Renewable Energy Laboratory (NREL) and the Nevada Test Site (NTS) to evaluate the integration of distributed energy resources into electric power systems.

- **Distribution System and Grid Support Applications.** When effectively integrated into an electric power system, distributed power systems can be used to provide high-value energy, capacity, and various ancillary services such as voltage regulation, power quality improvement, and emergency power. However, achieving these benefits requires that these systems be carefully integrated with the electric power system. DOE has several contractors that are examining issues related to using distributed resources for energy management and grid support applications.

Through these efforts, DOE is working with manufacturers and trade associations to advance and improve interconnection and distribution systems.

4.2 Electric Distribution System of the Future

Current R&D activity will contribute to the realization of the electric distribution system of the future. At their core, future distribution systems embracing SMARTConnect™ technologies will be structured and operated to provide local control authority for:

- Actions that must be taken quickly (e.g. local voltage regulation).
- Aggregation and balancing of generation and load.
- Maintaining the distribution voltage and frequency within limits specified by a central control authority.
- Dispatching reliability services (spinning reserve, black start, etc.) in response to commands from a central control authority.

Future distribution systems will also have the following key capabilities:

- A layered control system that satisfies the needs of the customers, the local distribution system and the transmission grid. A well-defined hierarchy of priorities must be provided in the control logic.
- A protection system that will accommodate routine two-way power flow with localized generation/storage.
- Ability to rapidly change configuration, island, re-align, start and stop generation.

The "smart" electrical distribution system and substation of the future will handle 2-way electrical flows as well as communications that permit all interconnected DER to be dispatched, monitored, and controlled from a central source. The distribution system will rely on upgraded substations that incorporate remote terminal units with improved capabilities for monitoring and reporting, GPS, electric equipment diagnosis, real-time video capturing and transmission, audio signature analysis and substation security supervision. Advances in low-cost communications networks, sensors and controls, energy storage, and power electronics will enable the connection of large numbers of DER to the grid in a fully functional manner and in turn will actually result in greater reliability, improved efficiency, and improved power quality.

Hierarchical control systems and distributed, intelligent agents will overlay local decision-making with a systems hierarchy, composed of supervisors of increasing sophistication. This framework allows decision-making to be pushed down to the lowest level and results in a number of operational benefits, including higher speeds of communication and control and the availability of much more detailed information to the central control authority when necessary.

Low-cost sensors and fast local communication systems with embedded intelligence will allow DER systems to seamlessly integrate with the electrical distribution system and to operate cooperatively and autonomously. The modernized and highly automated distribution system will support remote monitoring of device performance, dynamic and optimized aggregation, and the detection of system faults, instabilities, and congestion problems.

SMARTConnect™ distribution system technologies will become an integral part of control and switching devices throughout the distribution system. The distribution system of the future may include a DC bus, high frequency AC networks, and possess "self-healing" capability. This last characteristic is especially important in dense distribution systems where a fault can take hours of trial and error to locate and repair. For example, a foreign utility recently developed a system capable of automatically detecting and isolating a fault on a feeder, and then restoring power to the feeder within 20 seconds of the fault[5]. The key to feeder restoration is the connection, through normally-open switches of the feeder, of the fault with an adjacent feeder. Once the faulted section is isolated, the automated supervisory system closes the appropriate switch, restoring power to the feeder[6].

In short, tomorrow's distribution system will be smart, flexible and more reliable than today's. Instead of struggling to interconnect today's DER prime movers with today's electric distribution system, through SMARTConnect™ developments the interconnection of additional DER resources will be nearly seamless. Much of this development will happen as utilities deploy increasingly smart components when maintaining, replacing or upgrading their distribution systems. Utilities are expected to do this because they will increasingly be competing with customer-owned DER, but most importantly, they can lower their O&M costs when newer technologies are used, and public utility commissions prefer lower annual costs. In other words, tomorrow's distribution system will evolve as new technologies are inevitably deployed. Targeted R&D efforts today can speed this process along by mitigating barriers and improving the underlying technologies.

4.3 Priority R&D Needs

While not all priority R&D needs will be performed nor funded by DOE or the government, it is useful to consider a list of key knowledge and implementation gaps in current practice before defining the activities DOE plans to take during the next few years.

Beyond mitigating regulatory and institutional barriers, to achieve the proposed electric distribution system of the future, a number of new technologies and standards need to be developed, including:

- New protection schemes (e.g., fault detection, anti-islanding, controlled islanding) for two-way power flow.
- System control models that incorporate automatic local contingency response.
- Interfaces that control power flow, voltage and frequency.

[5] "High-Speed Fault Detection and Power Restoration in Taiwan", Utility Automation Magazine, Volume 7, Number 2, March/April 2002, page 20.
[6] Remote terminal units located on the feeder measure voltage magnitude and phase angle on either side of the switch and can also act as permissive synch-check relays. This ensures that reclosure is within tolerances.

- Advances in low-cost communication and control networks and advanced SCADA that enable aggregations of DER to be an integrated operation with the scalability to meet individual user, facility, and utility requirements.
- Digital programmable relays, improved sensors and controls, and expert systems that enable real-time dispatch and monitoring of DER units.
- Real-time monitoring equipment for incipient fault detection and self-repair.
- Standards that clearly state the requirements for interconnection of DER equipment.
- Modular, standardized interconnection devices that allow DER to be readily and inexpensively interconnected with the electrical distribution system.
- Modifications to the electrical distribution system that increase its reliability, lower maintenance costs, and ensure secure operations in the face of crippling natural or terrorist activities.
- Low-cost converter technologies that enable direct current distribution networks.
- Improved distribution system VAR support without necessarily adding new generating capacity.
- Smart substation designs that allow real-time control of DER microgrids and other DER units interconnected to the substation's distribution feeders.

DOE is planning to address several of these priority R&D needs, as outlined in the next Section. Manufacturers or utilities deploying new technologies may address the others.

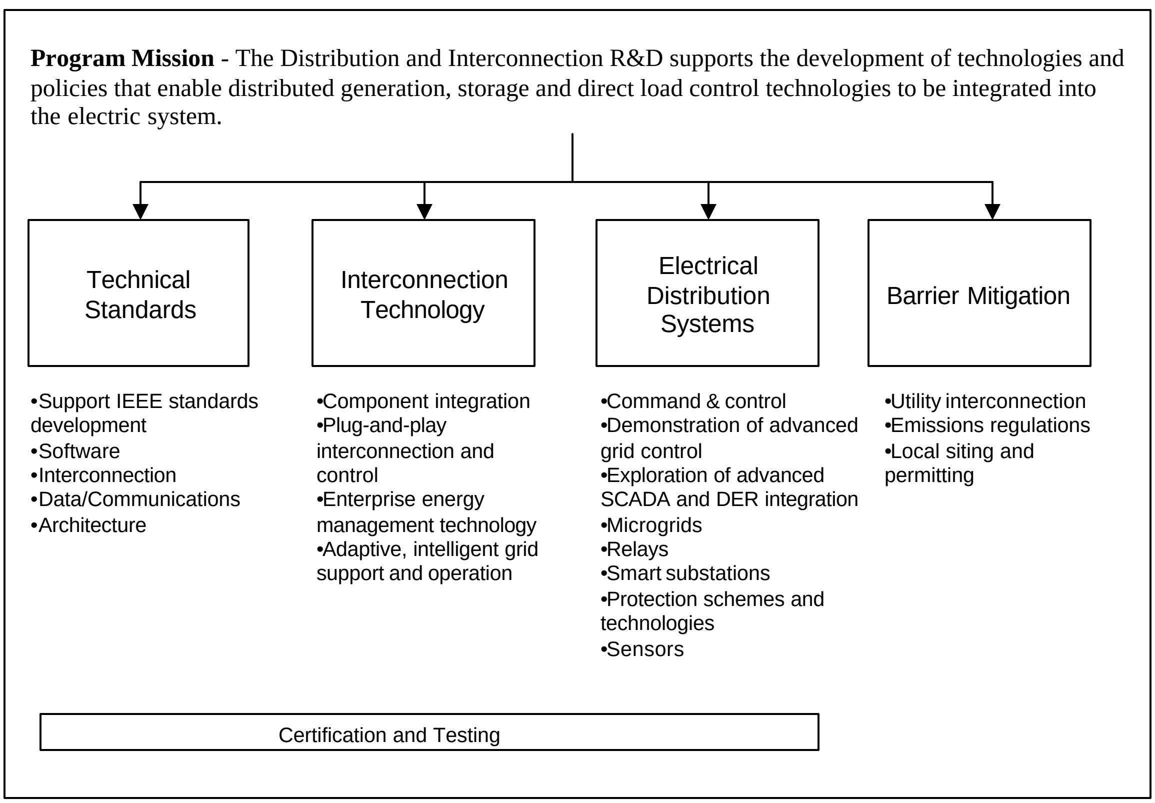
5 Distribution and Interconnection R&D Activities, Performance Targets and Time Frames

Distribution and Interconnection R&D conducts research, development, and deployment of electric distribution systems; DER interconnection and system integration technologies; and on regulatory activities that remove technical, institutional and regulatory barriers impeding realization of the full potential of DER. This is accomplished through a collaboration of national laboratories and industry partners, strategic research, system integration, and the mitigation of regulatory and institutional barriers. The proposed R&D Strategic Roadmap focuses on implementing the government-funded portion of an overall industry-driven roadmap. Specific goals include:

1. By 2010, develop and publish a body of technical standards facilitating the commercialization of mass-produced, certified interconnection equipment – simplifying the interconnection process.
2. By 2010, as one platform of SMARTConnect™ technology, develop a modular interconnection device that allows plug-and-play interconnection of DER equipment.
3. By 2010, identify and remove regulatory and institutional barriers to DER.
4. By 2015, develop next generation distribution technologies that make distribution systems more reliable, efficient, adaptable, secure, and fully integrate DER.

By 2010, overall program activities will help reduce the cost of interconnection by 30 percent while improving interconnection performance. *Distribution and Interconnection R&D* focuses on four topical areas, all impacting the streamlined, safe and efficient integration of DER into our electric distribution system, plus cross-cutting certification and testing efforts. The areas and activities are shown in Figure 3.

Figure 3. Distribution and Interconnection R&D Activities



5.1 Technical Standards

A lack of interconnection standards has severely curtailed the application of distributed resources. Interconnection requirements are different from location to location and often different from time to time. It is often necessary for a utility to study each proposed installation before requirements can be established. This has resulted in increased effort, time, and cost for those wishing to use DER. There can also be the perception that commercial considerations influence the interconnection requirements being imposed.

With support of DOE's *Distribution and Interconnection R&D*, the National Renewable Energy Laboratory (NREL) is facilitating the development of an IEEE interconnection standard, IEEE Standard P1547, Draft Standard for Interconnecting Distributed Resources with Electric Power Systems. Over 300 members have been participating on the P1547 Working Group, and members actively support the need for the standard. Once the standard is complete, more work will be required to support the development of related standards as well as an update of Standard 1547. Progress is likely to accelerate once regulators, owners, and utilities have experience with DER installations and can better judge actual problems and benefits.

Currently, technical requirements for interconnecting DER with electric power systems vary by state and utility. These requirements often represent a major cost for small system installers. Engineering studies or additional protective hardware are often required that appear unnecessary to installers. The absence of simple standardized applications and agreements for interconnection can delay DER projects. Utility rates also discourage export of power to the grid. Many utilities have legitimate concerns about losing load and market share, "cream skimming," and stranded assets.

Concurrently, electrical, mechanical, and fire safety standards are being developed, along with a process for certification of interconnection systems, to facilitate local permitting as well as interconnection with the utility system. Underwriters Laboratories standard UL 1741, which currently applies only to photovoltaic inverter systems, is being revised to include interconnection systems for all distributed generation and storage technologies. Computer simulations, laboratory testing, and field-testing are being conducted to validate the technical standards being developed.

The Distribution and Interconnection R&D technical standards activities cover:

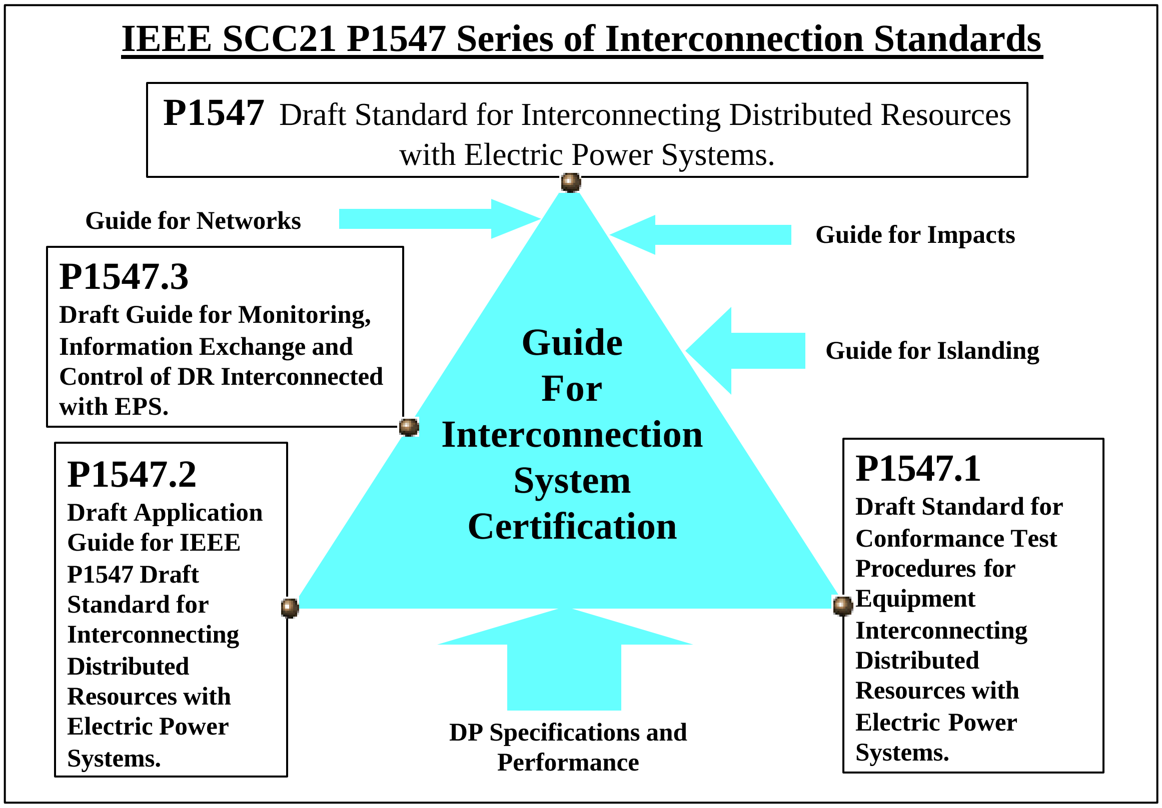
1) Technical standards development,
2) Examination and testing of options for interconnection with the electric power system,
3) Electrical/fire/mechanical safety standards,
4) Data/communications standards,
5) Software development and testing,
6) Research on electrical system integration architecture, increased modularization, and testing of a seamless physical connection, and
7) Aligning IEEE standards with national codes (e.g., NEC).

Goals. Specific goals include drafting and approving a body of interconnection standards, including the following IEEE standards:

- IEEE P1547, Standard for Interconnecting Distributed Resources with Electric Power Systems
- IEEE P1547.1, Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
- IEEE P1547.2, Application Guide for IEEE P1547 Standard for Interconnecting Distributed Resources with Electric Power Systems
- IEEE P1547.3, Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems.

Figure 4 shows the relations between these standards activities. Each standard is then described.

Figure 4. Existing IEEE SCC21 Standards Development Projects (P1547 Series) and Potential Future Activities Under Discussion by SCC21 Work Group Members



IEEE P1547, Standard for Interconnecting Distributed Resources with Electric Power Systems– DER installations are becoming more prevalent, and there has been a push for a national standard for DER interconnection. IEEE is in the process of developing IEEE P1547 – Standard for Distributed Resources Interconnected with Electric Power Systems. This standard will define the minimum functional technical requirements that are universally needed to assure a technically sound interconnection. The standard provides uniform criteria and requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection equipment. Revisions of P1547 will address the high penetration of DER and allow DER to provide services and support for utilities, not just a disconnect from the utility.

IEEE P1547.1, Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems– This standard specifies the type, production, and commissioning tests that shall be performed to demonstrate that the interconnection functions and equipment of a DER conform to IEEE Standard P1547. Standardized test procedures are necessary to establish and verify compliance with those requirements. These test procedures must provide both repeatable results, independent of test location, and the flexibility to accommodate a variety of DER technologies.

IEEE P1547.2, Application Guide for IEEE P1547 Standard for Interconnecting Distributed Resources with Electric Power Systems – This guide provides technical background and application details to support the understanding of IEEE P1547. This document characterizes the various forms of distributed resource technologies, and associated interconnection issues, and discusses the background and rationale of the technical requirements in terms of the operation of the distributed resource interconnection with the electric power system (EPS).

IEEE P1547.3, Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems – This document provides guidelines for monitoring, information exchange, and control for DER interconnected with EPSs. This document facilitates the interoperability of one or more DER interconnected with EPSs. It describes functionality, parameters and methodologies for monitoring, information exchange and control for interconnected DER with, or associated with, EPSs.

In addition, distribution system technical standards will be reviewed to ensure that they allow for proper DER interconnection into the distribution system. Recommendations will be made to ensure they are compatible with the new IEEE DER interconnection standards.

Metrics, Performance Targets and Timeline. The *Distribution and Interconnection R&D* technical standards activity will result in the development and approval of the four IEEE DER Interconnection standards previously listed. Table 3 notes performance targets and timelines for these technical standards activities.

Table 3. Technical Standards Performance Targets and Timeline

Technical Standards	FY02	FY03	FY04	FY05	FY06	FY07
IEEE P1547 Standard for Distributed Resources Interconnected with Electric Power Systems						
Launched March 99, First Ballot March 2001						
Approved	X					
Published		X				
Revision 1			X			
Revision 2						X
IEEE P1547.1 Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems						
Launched	X					
Voting Draft			X			
IEEE P1547.2 Draft Application Guide for IEEE P1547						
Launched	X					
Voting Draft			X			
IEEE P 1547.3 Guide for Monitoring, Information Exchange and Control of Distributed Resources						
Launched	X					
Voting Draft				X		
Distribution Systems Standards Review						X

Implementation. DOE, through NREL and other activities, is leading the development of these standards by heading committees, organizing meetings, and helping to write the standards. During the development process for each standard, the following activities are planned:

- Identify and collect reference material.
- Form research and writing teams.
- Develop preliminary drafts of guide.
- Conduct coordinated review process.

- Track/incorporate updates of other related standards.
- Produce "consensus" draft for ballot.

After approval, only widespread acceptance and use of the technical standards will determine the importance of these efforts.

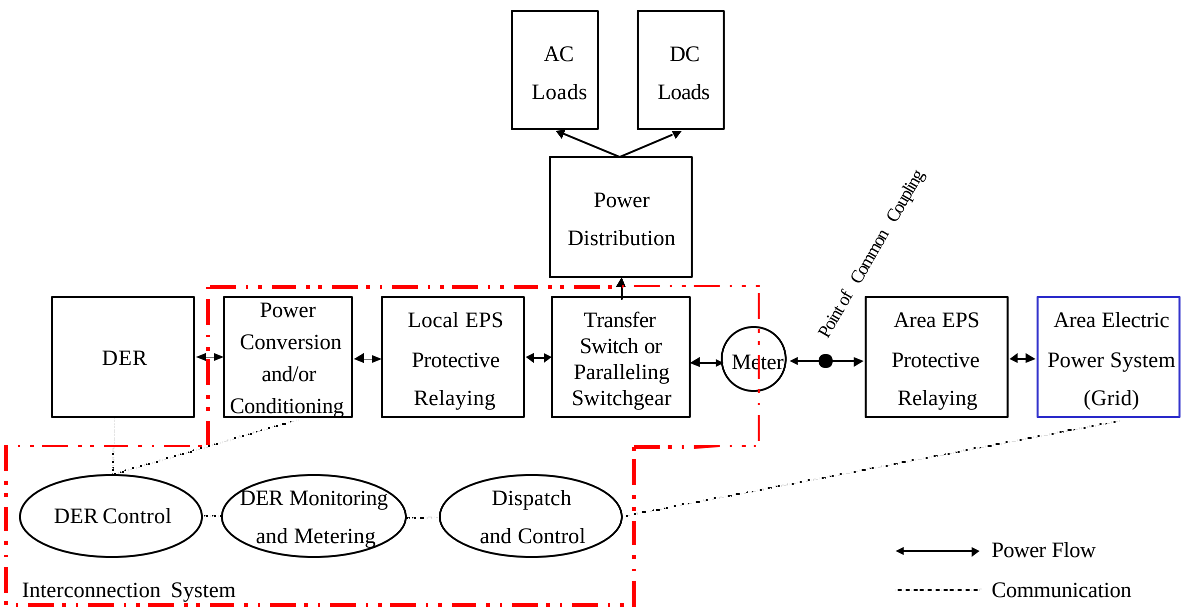
5.2 Interconnection Technology and Systems Integration

An interconnection system is the equipment that makes up the physical link between DER and the area electric power system (Area EPS), usually the local electric grid. The interconnection system is the means by which the DER unit electrically connects to the outside electrical power system, as well as provides one or more of the following: local and/or remote monitoring, local and/or remote control, metering, and local and/or remote dispatch of the DER unit.

DER applications are interconnected to the Area EPS for a reason – the host site wants the ability to use both the DER and the Area EPS, sometimes simultaneously. The owner of the Area EPS can also receive benefits from DER interconnections, but wants to be sure the interconnection is safe and does not affect Area EPS reliability or power quality.

The complexity of the interconnection system depends on the level of interaction required between the DER, the customer loads, and the Area EPS. Figure 5 shows a typical interconnection system.

Figure 5. Typical Interconnection System



The interconnection system (within the dotted line) is designed to handle the power between and serve as the communication and control highway between the DER, the Area EPS and the customer's loads. These interactions can occur quickly (e.g., on the order of milliseconds or cycles) in the case of voltage and frequency regulation, reactive power supply and fault protection and coordination, or more slowly (e.g., on the order of seconds or minutes) in the case of power export or peak shaving.

The task of overall system design and ensuring that the various components of the energy infrastructure effectively communicate and work together as planned is called systems integration. Effective systems integration requires an overall design concept clear enough to achieve necessary coordination of the growth and operation of the energy networks, while allowing customer choice in finding the right balance between central control and distributed intelligence. Deployment of distributed energy resources on a large scale will require integration into a complex electric distribution system of more than 10,000 power plants and nearly 3,500 utilities.

Distributed energy resources use sensors and control systems for measuring power output, revenue metering, conveying real-time price signals, data acquisition, and communications. Remote dispatch of distributed energy resources can be a cost effective means for aggregating dispersed power supplies, or demand management capabilities, into larger resources to support grid operations. Efforts are underway to develop interconnection technologies that provide these capabilities and are cost effective for smaller scale power generation devices.

Distribution and Interconnection R&D will help ensure that distributed energy technologies support electric grid reliability and that gas-fired distributed generation integrates into both the electric and natural gas systems for maximum efficiency, security, and reliability.

The Distribution and Interconnection R&D Interconnection Technology and Systems Integration activity will cover:

1) System integration R&D,
2) Increased component integration,
3) Development of cost-effective advanced modular plug-and-play interconnection and control technologies (formerly known as Universal Interconnection Technology devices),
4) Enterprise energy management systems and resource planning research and testing, and,
5) The application of automated, adaptive, intelligent technology to aggregate DER, and provide grid support, ancillary services, and load/demand management.

Selected modeling, along with laboratory and field testing, is also planned. Related software and communication solutions are applicable to improving the functionality and economics of a broad range of DER power systems. Results are expected to yield lower interconnection costs as well as enhanced features (i.e. load management and the increased ability to sell energy and ancillary services into electricity markets). Near-term research on inverter-based systems focuses on developing modular and perhaps universal interconnection technologies that reduce the need for custom designs for different DER technologies and manufacturers, and on increasing the reliability of inverter-based technology to 10 years mean time between failures (MTBF). Research on switchgear-based systems for synchronous generators is targeted at increasing the solid-state integration of utility-grade switchgear, metering, and communications together with other DER and load control and protection functions. Technology for the aggregation and control of DER in microgrids and other enterprises is also being researched.

An important part of systems integration is the development of national consensus-based standards to allow manufacturers and system designers to work out technical specifications of various functions and interfaces, thereby allowing components and systems to be designed to a common standard architecture. These standards are currently in development (see Section 5.1).

Additionally, even after the standards are developed by such groups as the American Society of Mechanical Engineers (ASME), the American National Standards Institute (ANSI), and the Institute of Electrical and Electronics Engineers, Inc. (IEEE), the testing and certification of components by testing organizations must be accomplished.

Goals. The goals are to develop the following interconnection technologies:

- Increase component integration by developing modular interconnection technologies that allow for easy DER interconnection (ideally plug-and-play).
- Inverter-based interconnection systems across multiple DER technologies (2 kW – 500 kW).
- Fully integrated utility-grade interconnection systems with switchgear, metering, and system-level command and control for synchronous machines (< 3 MW).

Metrics, Performance Targets and Timeline. Metrics for this part of the program include:

- Reducing the overall cost of interconnection by 15% by 2005 and 30% by 2010.
- 10-year MTBF for inverter-based technology by 2005.

Table 4 gives performance targets and a timeline for these activities.

Table 4. Interconnection Technology and Systems Integration Targets and Timeline

Interconnection Technology / Systems Integration	FY02	FY03	FY04	FY05	FY06	FY07
Non-inverter Interconnection Technology						
Concept	X					
Module Design		X				
Prototype Modules			X			
Prototype Testing					X	
Inverter Interconnection Technology						
Concept	X					
Module Design		X				
Prototype Modules			X			
Prototype Testing					X	
Integration into SMARTConnect™ Solution						X

Implementation. The following activities are currently planned for 2003:

- Development of working definitions for core modular interconnection functions,
- Development of interconnection system functional block diagrams for a variety of DER configurations,
- A series of one-day workshops to refine the functional block diagrams for the modular interconnection device, and the identification of core technology:
  - One workshop to develop a functional diagram for non-inverter applications,
  - A second workshop to develop a functional diagram for inverter-based applications,
  - A third workshop to synthesize the inverter and non-inverter diagrams into a single modular interconnection device employing a set of enabling technologies, and develop a technical requirements document, and
- Development of a detailed step by step plan for further defining the individual pieces within each modular interconnection block diagram and the interfaces between them.

Further development of the modular interconnection platform of SMARTConnect™ technologies will define activities in 2004 and beyond.

5.3 Electrical Distribution Systems

One of the solutions to our energy challenge is to integrate DER into the electric distribution system so that they are a functioning part of the system. Fully integrating DER into the electric distribution system will maximize benefits to the consumer and U.S. industry: these distributed resources are clean, efficient, reliable and affordable, and provide flexible power to meet fluctuations in demand.

Distribution and Interconnection R&D's efforts are key to meeting goals for the future, as the distribution system is a critical energy system component. The reliable delivery of electricity depends upon a complete infrastructure that integrates power generation and demand response into an efficient and reliable delivery network. With the rapid, and in some cases unexpected, growth of both conventional and technology-based loads, increasingly this system is heavily taxed. As evidenced in California, this situation can often lead to shortages, and new generation and transmission often cannot keep up with load growth. Ninety-four percent of U.S. electric generation flows through distribution systems. Technologies developed by *Distribution and Interconnection R&D* activities will improve the nation's distribution systems, and will have wide ranging benefits for society as a whole.

DER can make electric distribution systems much more reliable, efficient and competitive, but power distribution systems were not designed to accommodate active generation and storage at the distribution level, particularly to supply energy to other distribution customers. It can be difficult to interface DER with an existing grid that is designed for one-way power flows. Other issues such as system protection, metering, and basic design difficulties heighten this challenge. Until these issues are addressed, DER interconnection problems are likely to persist. New interconnection technology and systems integration techniques will need to be developed along with hardware and software that enable these techniques to be implemented. This includes development and testing of advanced relays and alternative distribution system protection devices.

Goals. Activities will help create the foundation needed to address these issues. While advanced inverters can help reduce or even eliminate the interconnection problems that currently plague DER, distribution system side R&D can also be helpful. Electrical distribution systems will be evaluated to see how and if they can be modified to accommodate DER interconnection. Advances that reduce the costs to utility distribution systems of the modifications necessary to safely interconnect DER are essential.

Modeling and testing during development of the interconnection standard to date has highlighted the need for changes in utility distribution system operation and technology in order to achieve the benefits of significant DER penetration. *Distribution and Interconnection R&D* will apply existing technology and develop advanced technologies to implement new distribution system architectures and operational concepts that allow the grid to integrate and exploit the benefits of significant penetrations of DER. These activities will conduct R&D on the microgrid concept, system architectures, power system issues (such as interactions with other elements on the microgrid), system protection and safety. Specifically, activities will cover:

- Distribution system technology and needs assessment,
- Research and development on intentional islanding and protection technology,
- Interconnection certification process,
- Development and testing of advanced protection scheme designs,
- Development of a microgrid integration and operation concept, and
- Research on sensors and controls.

Utility distribution systems must be characterized to determine their capabilities to accommodate DER devices. Modifications that might be practical to increase the ability of various types of utility distribution systems to exploit DER benefits for all utility customers should also be investigated. Advanced utility distribution system designs should be developed such that the limitations of existing systems are not propagated into the future. A concurrent step will be to develop computer simulation models of the distribution system that assess alternative situations. These validation tests will require a prototype inverter, sensors and communication systems. The simulation models will first be tested in the laboratory and then in the field.

Metrics, Performance Targets, and Timeline. *Distribution and Interconnection R&D* will initially focus on closer examination of 1) protection schemes and 2) intentional islanding. Performance targets and a timeline for these and subsequent activities are provided in Table 5.

Table 5. Electric Distribution Systems Performance Targets and Timeline

Distribution Systems	FY02	FY03	FY04	FY05	FY06	FY07
Distribution System Technology Needs Assessment		X				
Operational / Technical Concepts for Intentional Islanding			X			
Interconnection Certification Process			X			
Protection Schemes						
Model Existing Schemes	X					
Characterize Digital Technologies		X				
Advanced Protection Schemes Design			X			
Demonstration and Deployment				X		
Demonstration of Micro Grid Operation				X		
Sensors and Controls R&D				X	X	
Advanced Grid Control, Advanced SCADA, Smart Substations						X

Implementation. DOE, through NREL and other activities, including laboratory and field testing, will develop a *Distribution System Interconnectability Assessment* report. In addition, a *Microgrid Integration and Operation Concept* will be developed. The end result will be finalized recommendations for distribution systems that allow for easier DER interconnection. In later years, work will be conducted to take further steps toward advanced grid control, advanced SCADA and the development of smart substations.

5.4 Barrier Mitigation

Several technical, economic and institutional barriers interfere with the expanded installation of distributed energy systems, including:

- Utility interconnection and related tariffs,
- Emissions regulations, and
- Local siting and permitting.

Technical interconnection requirements for DER may differ from utility to utility and state to state. Customers attempting to install these technologies may also be required to pay for pre-interconnection engineering studies, which can add significant cost to the system. The typical lack of a single utility point of contact or defined process for distributed generation interconnection matters. The absence of simple standardized applications and agreements serve to delay and discourage customer-owned projects.

Utility use tariffs and rate design as a rule do not price distribution services to account for system benefits that could be provided by distributed generation. More appropriately designed tariffs can provide for standby and backup power services without incurring prohibitive charges. Standby services include power to supplement or replace a customer's on-site generation. Backup services include power supplied to a customer during an unscheduled or emergency outage of their on-site generation.

Zoning, air permitting, water use permits, comprehensive environmental plan approval, and other regulatory processes can both delay and increase the costs of distributed power projects. These issues typically relate to site-specific concerns. In general, distributed power technologies are not covered in national building, electrical, and safety codes. The codes do address photovoltaics; but this was the result of many years of effort by DOE, its national laboratories, standards organizations and industry. Local code and zoning officials are typically not familiar with DER technologies, nor is there recognition of DER's benefits. Environmental regulations are not currently administered in a way which gives credit for the overall pollution reduction effects of high efficiency distributed power technologies such as combined heat and power systems.

Existing business practice and business models often reflect the old regulated electricity industry dominated by vertically integrated utilities and central station power plants. New business models are needed to capture the values of non-utility owned distributed power in delaying or avoiding transmission and distribution system upgrades, the use of DER for ancillary services and for improving system reliability, power quality and reducing line losses. In brief, new competitive business models need to be developed that will allow the realization of the full economic value of DER in competitive markets.

To address these and other barriers, industry groups and government agencies are working together to support the development of better environmental siting and permitting regulations, more effective building codes and standards, and more open and competitive utility markets and business practices. The aim is to streamline procedures, accelerate distributed energy project development timetables, and lower unnecessary costs of regulatory compliance.

Distribution and Interconnection R&D is documenting and removing the regulatory and institutional barriers to DER deployment and the steps taken to overcome them. As developed in the report, *Making Connections: Case Studies of Interconnection Barriers and their Impact on Distributed Power Projects*, the barriers to interconnection of DER with the utility grid include:

- Varying interconnection requirements,
- Excessive back-up charges,
- Exit fees,
- Procedural delays,
- Selective discounting, and
- Insurance and indemnification requirements.

In addition, local siting and permitting, including environmental permitting, can be problematic. *Distribution and Interconnection R&D* is working with industry and state and local government organizations to eliminate unnecessary barriers to DER created by current policies, regulations, and business practices. Assistance is provided to states

Making Connections: An Action Plan

Reduce Technical Barriers

- **Adopt uniform technical standards for interconnecting distributed power to the grid**
- **Adopt testing and certification procedures for interconnection equipment**
- **Accelerate development of distributed power control technology and systems**

Reduce Business Practice Barriers

- **Adopt standard commercial practices for any required utility review of interconnection**
- **Establish standard business terms**
- **Develop tools for utilities to assess the value and impact of distributed power**

Reduce Regulatory Barriers

- **Develop new regulatory principles compatible with distributed power choices in both competitive and utility markets**
- **Adapt regulatory tariffs and utility incentives to fit the new distributed power model**
- **Establish expedited dispute resolution processes for distributed generation project proposals**
- **Define the conditions necessary for a right to interconnect**

developing DER rules, including workshops for state utility regulators and staff to increase awareness of regulatory barriers and examine potential solutions. Similarly, workshops are being conducted for local code officials who typically are not familiar with the newer DER technologies such as fuel cells and photovoltaics. Familiarizing local inspectors with these technologies and the applicable codes and standards will greatly facilitate the local permitting process.

Goals. *Distribution and Interconnection R&D* goals in the barrier removal arena seek to mitigate regulatory and institutional barriers by:

- Educating stakeholders such as regulators, policy makers, and building code designers about the benefits of DER,
- Integrating customer supply and demand solutions as parts of the Area EPS,
- Updating and perhaps standardizing utility interconnection requirements leading to improved business practices (see Section 5.1),
- Finding ways to implement equitable and innovative DER tariffs including interconnection fees,
- Updating emissions regulations to treat DER equitably, and
- Streamlining DER integration through improved local siting and permitting requirements.

Metrics, Performance Targets, and Timeline. Specific activities include developing:

- UL/ANSI 1741 standard/certification process to cover interconnection equipment for all DER,
- Model DER interconnection rule,
- Model emissions rule for small DER,
- Methodology to determine equitable rates for stand-by charges and backup fees, and
- Research on innovative tariffs for DER.

A metric has been set of 10 states adopting the DER interconnection and emissions rules by 2005. A timeline for these activities is provided in Table 6.

Table 6. Barrier Mitigation Performance Targets and Timeline

Regulatory and Institutional Barrier Removal	FY02	FY03	FY04	FY05	FY06	FY07
Making Connections - Report 2000						
Environmental Barriers	X					
Model Emissions Rule		X				
Barrier Update/Progress Review				X		
Methodology to Determine Equitable Rates for Standby Charges/Backup Fees			X			
Innovative Tariffs for DER			X			
10 States Adopt DER Interconnection Rule				X		
10 States Adopt DER Emissions Rule				X		

Implementation. DOE activities consist of developing the reports and rules summarized in Table 6 and while doing so, cooperating or coordinating with other related state- and national-level efforts.

5.5 Certification and Testing

Two fundamental supporting activities, testing and certification, cut across the four main areas of the *Distribution and Interconnection R&D*. Tables 7 and 8 provide performance targets and timelines for these supporting activities.

Table 7. Certification Performance Targets and Timeline

Certification	FY02	FY03	FY04	FY05	FY06	FY07
UL 1741 Inverters, Converters and Controllers for Use in Independent Power Systems (Revision/Expansion)						
Draft		X				
Final			X			
Certify Products				X		
NEC Compliant						X
Interconnection Equipment Certification						
Definition		X				
Design Program			X			
Implementation Handbook				X		
Implementation by Industry					X	
Lab Accreditation (i.e., ISO 25)						
First Commercial Application					X	
Process Review and Update						X
Industry Acceptance						‘07+
Quality Certification (i.e., ISO90001/9001)						
First Commercial Application						X
Process Review and Update						‘07+
Industry Acceptance						‘07+
Certification Authority (i.e., PAC)						
First Commercial Application				X		
Process Review and Update					X	
Industry Acceptance						X

Table 8. Testing Performance Targets and Timeline

Testing	FY02	FY03	FY04	FY05	FY06	FY07
DER Test Facility Operational Dec 2001 (up to 200 kW)						
DER System Interconnection Test Lab (up to 1 MW)						
Conceptual Design 2001						
Engineering Design	X					
Start Construction		X				
Operational			X			
National DER System Integration Field Test Facility (up to 200 MW)						
Pilot Field Test P1547 Draft 7	X					
Phase I Test P1547 Draft 9		X				
Phase II				X		
Results Fed to P1547 Revision 2					X	
Industry Collaborative Testing						
Characterization Performance Testing		X				
Baseline			X			
Advanced Equipment				X		
Test Method Development	X	X	X	X		

Implementation. Demonstrations are planned to test various configurations and topologies for independent operation, and also for supplying voltage regulation services and other ancillary services to the distribution system. Demonstration tests of microgrids and power parks are planned. Much of the laboratory testing will be performed at DOE Laboratories and much of the field-testing will be done at the Nevada Test Center.

6 DOE Distribution and Interconnection Roadmap

Development of this draft Strategic Roadmap was based on a series of meetings and workshops on this topic conducted over the last two years, and additional market and technology research and stakeholder interviews. The ultimate practicality and vitality of the Roadmap that emerges from the January 2003 meeting interaction and subsequent discussions will depend on the new industry input received. This represents a starting point for development and implementation of full-scale *Distribution and Interconnection R&D* activities. Industry stakeholders are encouraged to react, suggest and constructively critique.

Figure 6 roadmaps highlights of the *Distribution and Interconnection R&D* activities. There are many interrelationships among the rows in Figure 6. They are not drawn since the resulting highly networked chart would not clarify the situation. However, key example observations are offered, for example that the development of standards allows the implementation of certification and testing, and this in turn is anticipated to influence the revision of IEEE 1547 standards. There are similar interactions between interconnection technology development, electrical distribution systems development and barrier mitigation – each should not be developed in isolation from the other areas. These interrelationships are described within Tables 3 through 8.

When reviewing Figure 6 entries, keep in mind that these highlight the planned DOE activities. They do not comprise all industry-driven roadmap efforts but are the government-sponsored subset of activities.

6.1 Distribution and Interconnection R&D Organization

In implementing the activities described in Section 5, it is important to realize that these public efforts are targeted to assist industry with key cross cutting areas of basic research, but generally not specific development or engineering tasks. Toward fulfilling the strategic activities, DOE plans to organize specific efforts, including staff and resources, around each of the five interrelated activity areas previously described, namely:

- Technical standards,
- Interconnection technology,
- Electric distribution systems,
- Barrier mitigation, and
- Certification and testing.

While doing so, attention will be paid to coordinating necessary interactions between these areas and keeping them in synch with each other. NREL has been the lead national laboratory to date in many of these areas, with support from additional DOE participants.

As these activities are undertaken, the electrical distribution system of the future will materialize. This system will support an adaptive, intelligent grid that supports DER. DOE plans to coordinate with, and in some cases to collaborate with industry, to take the steps identified in Section 5 that will move toward this vision.

6.2 Industry Outreach

Industry efforts must necessarily make up the bulk of R&D efforts. Many stakeholders will participate both in performing the R&D, funding the efforts, and in deploying marketplace solutions. As such, industry's expanded roadmap of the R&D activities in this arena will be much broader overall than that depicted in Figure 6. Many of the ongoing activities described in Section 4.1 will be continued and built upon by industry during the next five years.

Figure 6. Distribution and Interconnection Roadmap

	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	→
Technical Standards	IEEE P1547 Published	IEEE P1547.1 Voting Draft IEEE P1547.2 Voting Draft	IEEE P1547.3 Voting Draft		IEEE P1547 Revisions Distribution Systems Standard Review	Body of Standards that Facilitate Mass Produced Interconnection Equipment
Interconnection Technology	Phase I Multiple DER Interactive Field Testing		Phase II Multiple Interactive DER Field Testing	Inverter and Switchgear Based Interconnection Systems		Plug and Play SMARTConnect Interconnection
Electrical Distribution Systems	Distribution System Technology and Needs Assessment	Concepts for Intentional Islanding Interface Certification Process	Advances in Protection Technology Microgrid Demo Approaches for Secondary Networks	Sensors and Control R&D		Advanced Grid Control Advanced SCADA Smart Substations
Barrier Mitigation	Model DER Interconnection Rule Model DER Emissions Rule	Methodology for Equitable Standby and Backup Fees	Innovative Tariffs for DER			Removal of DER Barriers
Certification and Testing	UL/ANSI 1741 Field Test Facility	Interconnection Certification Interconnection Test Lab Industry Testing	Certification Authority Advanced Equipment Testing	Interconnection Certification by Industry Lab Accreditation	Industry Accepts Certification Authority UL 1741 NEC Compliant	Ongoing Certification and Testing

To help carry out its mission, *Distribution and Interconnection R&D* will continue to create partnerships with utilities, energy companies, manufacturers, interconnection end-users, state and local governments, universities, non-governmental organizations, and the national laboratories to advance the development of interconnection technologies. Such alliances help maximize the efficiency of the technology R&D process by leveraging public and private resources, and by bringing together interdisciplinary teams of scientists, engineers, and analysts to deliver technology results necessitated by the energy markets. Current SMARTConnect™ partners include the following (also see the DPP web site and its links):

- California Energy Commission (CEC)
- DTE Energy
- Electric Power Research Institute (EPRI)
- Electric Power Research Institute Power Applications Center (EPRI-PEAC)
- Electrotech
- Encorp
- Engine Manufacturer's Association (EMA)
- Gas Technology Institute (GTI)
- Institute of Electrical and Electronics Engineers (IEEE) Standards Association
- National Association of Regulatory Utility Commissioners (NARUC)
- National Council of State Legislatures.
- National Rural Electric Cooperative Association (NRECA)
- New York State Energy Research & Development Authority (NYSERDA)
- NiSource
- NRECA
- NYSERDA
- Orion
- Real Energy
- University of Wisconsin

The following additional stakeholders will also benefit from *Distribution and Interconnection R&D*:

- Interconnection equipment manufacturers and distributors,
- DER end-users, and
- Electric Power Distribution system operators and owners.

6.3 Funding

Bridging the R&D knowledge gaps will take considerable funding and time. As one measure of this, EPRI's 1999 Electricity Technology Roadmap estimated 10-year R&D funding needs for the distribution system of the future to be $400 million annually[7] over the next ten years. EPRI's funding focus was on cost-effective distributed generation technologies, interconnection standards, and control and protection systems for mixed central/distributed systems. Some emphasis was also placed on developing direct current distribution networks and VAR support without new generating capacity.

During FY 2002, approximately $133 million was budgeted by DOE to cover all aspects of the Distributed Energy and Electric Reliability (DEER) Program. Roughly 42 percent of this funding ($56 million) was directed toward distributed generation technology development, 25 percent ($33 million) applied to high temperature superconductivity R&D, and the remaining 33 percent ($44 million) was

[7] Electric Power Research Institute, *The Electricity Technology Roadmap Initiative*, www.epri.com/corporate/discover_epri/roadmap/roadmap_c2.pdf, 1999.

directed to end-use systems integration and interfaces. About 4 percent of the $133 million total ($5 million) was allocated to the *Distribution and Interconnection R&D* area.

Just to provide perspective, Table 9 roughly allocates the EPRI-estimated funding requirements into activity areas that are being pursued by *Distribution and Interconnection R&D* as well as other parts of DEER. In Table 9, distributed generation technology funding from DEER has been incorporated, assuming that this funding level is adequate with a 200 percent match from industry. Given this, the majority of needed funding translates into additional funding or industry co-funding in the area of distribution and interconnection R&D, which is a substantial portion ($232 million) of the estimated $400 million annual funding need. While DOE's FY2002 budget of $5 million can be leveraged to some degree with industry co-funding, it lacks the strength of funding devoted to other areas of need such as distributed generation technology.

Table 9 does not count the considerable cost (probably tens of billions of dollars) of deploying the results of the R&D and the resulting technology across the nation's electrical distribution system. Clearly both public and private resources will be needed to do it all.

Table 9. Estimated Annual R&D Funding Need ($M)

Activity Area	Current DOE Funding	Industry Co-Funding or Additional Funding Need	Total Funding Need
Distribution and Interconnection R&D	5	227	232
Distributed Generation Technology R&D	56	112	168
Total	61	339	400

DOE's preliminary plans for the immediate future include subcontract funding efforts including the recently closed DOE solicitation for Letters of Interest in the DER arena. That solicitation requested respondents focus their proposals within a range of activities related to interconnecting and integrating distributed energy resources. These activities may be organized into four categories:

- An advanced modular interconnection technology,
- Field testing of DER for interconnection standards and electrical power systems configurations,
- Standards for DER system integration, interconnection and operation with electric power systems, and
- Analysis and research on alternative rates and tariffs for DER.

Given the critical national importance of developing new sources of energy, modernizing our electric generation and transmission system for our digital and computer-based economy, and providing greater threat protection for our electric power system, it is essential that DOE continue its research, development, demonstration, and deployment program for DER. These new resources are expected to become even more vital to the future energy independence and security of the United States.

The *Distribution and Interconnection R&D* FY2002 funding level was approximately $5 million as noted above, with the FY2003 proposed funding level at $6 million. As part of Table 9, this indicates that the

Federal government's planned share of R&D is about two to four percent (rising over time) of what is needed to research and develop the technology needed to develop the electrical distribution system of the future.

To accomplish the aggressive goals of this area, DOE will need considerable help from partners in the electricity industry, national laboratories and universities. With this help, *Distribution and Interconnection R&D* can help connect today with the potential of DER for the future.

6.4 Implementation Strategy

Given the limited funding base, public/private partnerships are the cornerstone for implementing this Strategic Roadmap. DOE has, and will continue to, fund selected efforts conducted by industry, universities, and others that move to fulfill the steps outlined in this Strategic Roadmap. Principally this involves shared collaborative research efforts that are more at the R end of the R&D scale than the D end of the scale. Criteria used to help determine government efforts include looking for research with widespread applicability, longer-term payback, more uncertain payback and therefore higher risk, and results that can be shared with the entire DER industry. As outlined, this includes basic research in electric distribution systems, national standards setting, and the testing and certification of hardware and software. Most specific engineering or applied science research will be funded by private industry.

Further annual requests for Letters of Interest are anticipated that seek industry assistance in conducting shared research. These solicitations are likely to request co-funding from the private sector to stretch the government's budget. Solicitations may also favor teamwork. All stakeholders will openly share research results so that further Strategic Roadmap implementation efforts build upon actual results and R&D overlap will be minimized.

While this Strategic Roadmap focuses on the next 5 years, it does not stop then. Ongoing efforts are expected for the next couple of decades as the electric distribution system evolves into a smart, reliable and DER supportive grid. Further steps will be outlined as implementation progress is made and this Strategic Roadmap is accordingly reviewed and updated.